# AGE-RELATED DIFFERENCES IN MEDICATION RISK TAKING

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Wing Lam Chong

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# AGE-RELATED DIFFERENCES IN MEDICATION RISK TAKING

Approved by:

Dr. Wendy A. Rogers, Advisor
School of Psychology
*Georgia Institute of Technology*

Dr. Christopher Hertzog
School of Psychology
*Georgia Institute of Technology*

Dr. Rick Thomas
School of Psychology
*Georgia Institute of Technology*

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# TABLE OF CONTENTS

# LIST OF TABLES

# LIST OF FIGURES

# SUMMARY

Prior studies on older adults' risk taking have paid little attention to the healthcare domain. The current study examined age-related differences in medication risk taking. Participants were 36 English speaking younger adults (55.6% females) between the ages of 19 and 26 ($M$ = 20.94, $SD$ = 1.55), and 35 English speaking older adults (60.0% females) between the ages of 67 and 80 ($M$ = 72.34, $SD$ = 3.09). We asked them to choose between hypothetical medications that differed in probabilities and outcomes of treatment success. To investigate the effects of risk-disadvantageous versus risk-neutral versus risk-advantageous situations, participants chose between a risky option and a sure option that had a higher expected value (risk-disadvantageous), between a risky option and a sure option that had equal expected values (risk-neutral), and between a risky option and a sure option that had a lower expected value (risk-advantageous). Overall, older adults were more risk averse. Older adults also showed a smaller increase in risk-taking tendency across risk-disadvantageous, risk-neutral, and risk-advantageous situations compared to younger adults, consistent with the idea that younger adults are more likely to use verbatim processing than older adults in making decisions (Peters et al., 2007; Reyna & Brainerd, 2011). Further examination of individual participant's medication risky choices revealed that younger and older adults could be essentially classified into three groups: younger adults who were sensitive to expected value differences between options, older adults who took fewer risks than did younger adults but were sensitive to expected value differences, and older adults who were extremely risk averse and exhibited no sensitivity to expected value differences (54.29% of the older adult sample). Post-hoc exploratory analyses found

that a variety of individual difference measures (i.e., education, perceived health, numeracy, health literacy, global cognitive ability, perceived severity of sickness) did not differentiate sensitive and insensitive older adults. This could indicate that other variables should be considered as an explanation for the large inter-individual variability in sensitivity among older adults. These findings emphasize the importance of designing decision aids to encourage older adults to take more (fewer) risks when risk taking is more (less) beneficial, and point to the need for improving the communication of outcome and probability information in medication risky decisions to older adults.

# 1. INTRODUCTION

When choosing between options in healthcare, the degree of risk involved is an important consideration that younger and older individuals must make. For example, they have to choose between painkillers that have different probabilities and magnitudes of treatment effectiveness. Older adults are more likely to have multiple chronic conditions, and thus they may need to make more choices. A National Health Interview Survey in 2012 showed that 86% of US older adults aged 65 or older have at least one chronic condition, and 61% have at least two chronic conditions, compared to 27% and 7%, respectively, of US adults aged 18 to 44 (Ward, Schiller, & Goodman, 2014). Insofar as older patients face medical decisions that involve risks, it is important to investigate how they make these decisions, and whether the decision process differs as a function of age.

## 1.1 Age-Related Differences in Risk Perception

Because older adults are likely to suffer from multiple illnesses that require them to choose between treatment options with varying probabilities of success, there is a need to study age-related differences in risk perception and risk taking. Age-related differences in risk perception have been noted. For example, when risk perception was evaluated based on participants' estimation of the risks of drug adverse events, older adults underestimated more frequently than did middle-aged or younger adults (Peters, Hart, Tusler, & Fraenkel, 2014). Furthermore, when a numeric format of information was provided, less numerate older adults underestimated risks more frequently than did other groups. However, for those who underestimated risks, risk perception was unrelated to willingness to take the drug, underlining the importance of examining risk taking directly. It is

necessary for research looking at medication risky decision making to investigate risk taking and not solely risk perception.

## 1.2 Age-Related Differences in Risk Taking

### *1.2.1 Risk-neutral decisions*

Most studies on aging and risk taking asked participants to make risk-neutral choices, which involve a risky option and a sure option that have equal expected values. The expected value of an option is calculated by multiplying outcomes by their respective probabilities, and taking the sum of the products (Bernoulli, 1954). A higher expected value represents a higher average value in the long run assuming the same option is chosen repeatedly.

A recent meta-analysis of these studies found that older adults were more risk averse than younger adults in making positively framed decisions (Best & Charness, 2015). Positively framed decisions refer to choices in which wordings such as "keep" and "save" are used to highlight the positive aspects and desirable outcomes of the scenarios. This finding can be explained by fuzzy-trace theory and the goal orientation framework.

Fuzzy-trace theory postulates that people simultaneously store and access two types of representations (Reyna & Brainerd, 2011; Reyna, Nelson, Han, & Pignone, 2015). A verbatim representation reflects the precise information. In contrast, a gist representation captures the subjective interpretation of information based on emotion, experience, level of development, and is vague and qualitative. In the context of the Asian disease problem (Tversky & Kahneman, 1981), a gist representation of a sure option of "200 people will be saved" would be "some people will be saved" whereas a gist representation of a risky option of "a one-third probability that 600 people

will be saved, and a two-thirds probability that no people will be saved" would be "some probability that some people will be saved, and some probability that no people will be saved." Hence, fuzzy-trace theory suggests that people would choose the sure option when they represent the positively framed situation at the gist level. Older adults are more likely than younger adults to rely on gist processing because they may have learned that it is a more effective means of making decisions (Peters, Hess, Västfjäll, & Auman, 2007). In addition, gist processing is relatively well preserved with normal aging although verbatim processing declines as people age (Reyna & Brainerd, 2011). Because older adults' decisions are more gist-based, they are more likely to choose the sure option in the positive frame.

Goal orientation is another approach that can account for the age-related differences in risk taking. Younger adults are likely to be growth-oriented whereas older adults may be more oriented towards maintenance and loss prevention (Ebner, Freund, & Baltes, 2006). When people focus on preventing loss, they are less likely to take risks in the positive frame.

Although Best and Charness' (2015) meta-analytic finding on age differences in positively framed choices was consistent with the prediction of fuzzy-trace theory, younger adults' higher risk-taking tendency in making negatively framed choices in large-amount mortality scenarios was not consistent with the theory. In terms of the negative frame, a gist representation of a sure option of "400 people will die" would be "some people will die" whereas a gist representation of a risky option of "a one-third probability that nobody will die, and a two-thirds probability that 600 people will die" would be "some probability that nobody will die, and some probability that some people will die." Hence, fuzzy-trace theory suggests that people would choose the risky option when they represent the negatively framed situation at the gist level. As previously discussed, older adults tend to show greater reliance on gist processing in making decisions compared to younger adults.

This leads to the expectation that older adults would be more risk taking in the negative frame. While no age differences were found in overall risk taking, younger adults were more likely to take risks in negatively framed large-amount mortality scenarios, which was not predicted by fuzzy-trace theory and thus demands further exploration.

In addition to the moderating effect of amount and scenario in the negative frame, the meta-analysis revealed an age by amount by scenario interaction in the positive frame (Best & Charness, 2015). That is, the age effect was found in small-amount financial and large-amount mortality scenarios, but not in large-amount financial and small-amount mortality scenarios. Younger and older adults' levels of risk taking depend on the scenario. Owing to the heavy focus on financial risk seeking scenarios and the Asian disease problem in the aging literature, past findings on age-related differences in risk taking may not generalize to medication decision making for several reasons.

First, older adults are likely to have more experience in making medication decisions than younger adults. Their increased experience might lead them to use more affective/experiential processing. For instance, older adults may use more personal information (e.g., one's own experience) versus the information provided in the task (e.g., probabilities) when choosing between medications (Hess, 2015). This might influence older adults' medication risk preferences.

Second, older adults, relative to younger adults, may find medication decisions more relevant to them. According to the selective engagement framework (Hess, 2014), task relevance may influence people's use of affective/experiential versus deliberative processing. When older adults find a task personally meaningful, they may engage more cognitive resources, resulting in smaller age differences in risk taking.

Third, physical functioning and health decline as people age, which might change older adults' sensitivity to medication outcomes (e.g., heightening their sensitivity to losses; Depping & Freund, 2011). Health status was associated with subjective perception of life-prolonging treatment outcomes (Winter & Parker, 2007). Therefore, younger and older adults might translate a specific medication outcome into different subjective values, which in turn affects their medication risk preferences. It is unknown whether risk-taking tendencies of older and younger adults in the medical domain would be similar to the patterns obtained in other domains.

We have preliminary data that suggest the patterns may, in fact, differ for medication decisions (Chong, Bixter, & Rogers, in press). We asked 18 younger and 18 older adults to choose between medications that differed in probabilities and outcomes of treatment success. Contrary to the idea that older adults may show greater risk aversion in the positive frame, they showed a trend to be more risk taking than younger adults when expected values of the options were equal.

*1.2.2 Risk-advantageous and risk-disadvantageous decisions*

Studies have also explored younger and older adults' risk taking tendencies in situations where risk seeking is advantageous or disadvantageous. From an economic perspective, an option with a higher expected value is better than an option with a lower expected value. This is also referred to as the expected value strategy. As predicted, Albert and Duffy (2012) found that older adults were less likely to take risks than younger adults. Moreover, when choosing between a sure option with a lower expected value and a risky option with a higher expected value, older adults were more risk averse than younger adults (as indicated by the graph, but no analysis was reported for these specific data). Analyzing trials on which the expected value of the risky option was more favorable than that of the sure option, older adults were shown to be more risk averse than people

of age 5 to 64 (Weller, Levin, & Denburg, 2011). On trials that had a less favorable risky option than the sure option, older adults showed a marginally significant trend to be more risk taking than other age groups (Weller et al., 2011). Thus, older adults were less risk taking than younger adults when risk taking was beneficial, and they tended to be more risk taking than younger adults when risk aversion was beneficial.

Based on Peters et al. (2007), and Reyna and Brainerd (2011), older adults have an increased tendency to use gist processing relative to younger adults. Thus, they may be less sensitive to the expected values of the sure and risky options and more likely to stick to their preferred options on risk-neutral trials than younger adults. Comparing the two age groups' choices on different types of trials, our study showed that younger adults were significantly more risk taking on risk-advantageous trials than on risk-neutral trials, but older adults did not take significantly more risks when risk taking was favoured (Chong et al., in press). The older adults were less responsive to the expected values of options, which could be attributed to age-related differences in sensitivity to probabilities and/or outcomes.

### 1.3 Overview of Study

Although older adults often have multiple medical conditions and need to make health care choices involving risks, past research has not assessed age-related differences in risk taking for medication decision tasks. Younger and older adults may show different patterns of risk preferences in the medical domain because of differences in decision experience, personal relevance of the task, and health status. The goal of the current study was to study age differences in medication risk taking when risk taking was advantageous, neutral, or disadvantageous. Younger and older adults were asked to make choices between medications that involved varying

probabilities and outcomes of treatment success. On risk-neutral trials, they chose between options that were equally favorable. On risk-advantageous trials, they chose between options that favored risk taking. On risk-disadvantageous trials, they chose between options that favored risk aversion.

There were two hypotheses as manipulation checks, and a hypothesis related to age differences. The first hypothesis was that both younger and older adults would be more risk taking on risk-advantageous trials than on risk-neutral trials. The second hypothesis was that both younger and older adults would be more risk taking on risk-neutral trials than on risk-disadvantageous trials. Given that gist processing is relatively preserved while verbatim processing declines with aging (Reyna & Brainerd, 2011), older adults may be less responsive to the precise probability and outcome information. The third hypothesis was that there would be an age by trial type interaction such that older adults, compared to younger adults, show a smaller increase in risk taking tendency in response to risk-advantageous trials and a smaller decrease in risk taking tendency in response to risk-disadvantageous trials.

# 2. METHOD

## 2.1 Participants

Participants were 36 English speaking younger adults (55.6% females) between the ages of 19 and 26 ($M$ = 20.94, $SD$ = 1.55), and 35 English speaking older adults (60.0% females) between the ages of 67 and 80 ($M$ = 72.34, $SD$ = 3.09) after exclusion of one older adult (the reason for exclusion is explained in the results section). Younger adults were recruited through the Georgia Tech online SONA system. Older adults were recruited through the Human Factors and Aging Laboratory Participant Registry.

All participants had at least 20/50 visual acuity for near vision (corrected or uncorrected) to ensure that they could see the stimuli. The majority of older adults were highly educated, with 89% reporting having some college or higher. Table 1 shows the means and standard deviations for self-reported health, number of prescriptive medications, number of over-the-counter medications, number of health conditions, numeracy (Lipkus, Samsa, & Rimer, 2001), health literacy (Baker, Williams, Parker, Gazmararian, & Nurss, 1999), and the Montreal Cognitive Assessment (MoCA; Nasreddine et al. 2005) within each age group.

**Table 1: Younger and older adults' scores on health and cognitive measures.**

| | Younger Adults | | Older Adults | | t-value |
|---|---|---|---|---|---|
| | *M* | *SD* | *M* | *SD* | |
| Self-reported general health[a] | 4.03 | .65 | 3.51 | .70 | 3.19** |
| Prescriptive medications[b] | .31 | .71 | 3.40 | 3.22 | -5.56*** |
| Over-the-counter medications[c] | .47 | 1.72 | 3.06 | 2.43 | -5.17*** |
| Health conditions[d] | .53 | .88 | 3.29 | 2.20 | -6.89*** |
| Numeracy[e] | 9.92 | 1.20 | 7.69 | 2.49 | 4.78*** |
| Health literacy[f] | 34.44 | 2.06 | 30.91 | 6.37 | 3.12** |
| MoCA[g] | 28.44 | 1.30 | 25.54 | 2.37 | 6.38*** |

[a]Self-reported health (1=poor, 5=excellent); [b]Prescriptive medications (the number of prescriptive medications taken each day); [c]Over-the-counter medications (the number of over-the-counter medications/supplements taken each day); [d]Health conditions (the number of health conditions); [e]Numeracy (the score out of 11 on the numeracy scale); [f]Health literacy (the score out of 36 on the health literacy measure); [g]MoCA (the score out of 30 on MoCA); ** $p<.01$, *** $p<.001$.

### 2.2 Materials

Every trial of the decision task consisted of a choice between two hypothetical medications which had different treatment outcomes and likelihood of success. The sure option had a 100% chance of some treatment success whereas the risky option had a variable outcome of treatment success. Participants were instructed to choose one of the medications for themselves.

There were four trial types: risk-neutral trials, risk-advantageous trials, risk-disadvantageous trials, and catch trials. On risk-neutral trials, the medications had equivalent expected values. On risk-advantageous trials, the medication with a sure outcome had a lower expected value than the medication with a variable outcome. On risk-disadvantageous trials, the medication with a sure outcome had a higher expected value than the medication with a variable

outcome. (See Figure 1 for an example of each of the three trial types. For complete instructions, see Appendix A. For the risk magnitudes and the number of days of recovery on all trials, see Appendix B.)

Four catch trials were included to ensure that participants understood the task, and made choices according to information provided on each trial rather than randomly. The medication that has 100% probability of leading to a fewer number of days towards full recovery, that is, the option that always leads to a better health outcome, was considered as the "rational" option. (For the four catch trials, see Appendix C.)

Participants completed 30 risk-neutral trials, 30 risk-advantageous trials, 30 risk-disadvantageous trials, and 4 catch trials.

An example of a risk-neutral trial:

You have been diagnosed with a bacterial infection. Which antibiotic medication would you choose?

| Medication A | Medication B |
|---|---|
| A 60% chance of fully recovering in 25 days<br>and<br>a 40% chance of fully recovering in 5 days | A 100% chance of fully recovering in 17 days |

An example of a risk-disadvantageous trial:

You have been diagnosed with a bacterial infection. Which antibiotic medication would you choose?

| Medication A | Medication B |
|---|---|
| A 60% chance of fully recovering in 25 days<br>and<br>a 40% chance of fully recovering in 5 days | A 100% chance of fully recovering in 13 days |

An example of a risk-advantageous trial:

You have been diagnosed with a bacterial infection. Which antibiotic medication would you choose?

| Medication A | Medication B |
|---|---|
| A 60% chance of fully recovering in 25 days<br>and<br>a 40% chance of fully recovering in 5 days | A 100% chance of fully recovering in 21 days |

**Figure 1 - Examples of different trial types**

We considered two ways of describing the treatment outcomes: “symptoms’ and “days it takes to fully recover from sickness.” We chose “days it takes to fully recover from sickness” because “symptoms” could lead to more variable interpretations than “days it takes to fully recover from sickness.” We decided to provide a specific illness (i.e., bacterial infection) to participants

because the level of risk taking would likely depend on the decision context and we aimed to control for the variability in the decision context. We asked participants to rate how severe they perceived the sickness to be and to provide the specific illness that they had in mind after completing the decision task. The percentage of time that participants chose the risky option indicated their level of risk taking.

## 2.3 Design

Age was a grouping variable. Trial type was a within-subjects independent variable. Level of risk taking was the dependent variable. Other descriptive variables were demographics and health, health literacy, numeracy, near and far vision, and global cognitive function.

## 2.4 Measures

### *2.4.1 Demographics and Health*

The demographic and health questionnaire, adapted from materials developed by the Center for Research and Education on Aging and Technology Enhancement (Czaja et al., 2006), was used to collect background information of participants. The demographic questions asked participants to indicate their gender, age, race, English-speaking background, socioeconomic status, and marital status. The health questions concerned participants' subjective and objective health status, as well as the number of medications they were taking at the time of the study.

### *2.4.2 Post-Task Self-Report Items*

Participants answered a question about their perceived severity of the sickness on a scale from one (not severe) to seven (severe), and a question about the specific illnesses that they were thinking about when they completed the medication decision task. (See Appendix D.)

### *2.4.3 Health Literacy*

The short version of the Test of Functional Health Literacy in Adults (TOFHLA) was used to measure participants' ability to read and understand health-related materials (Baker et al., 1999). The S-TOFHLA consists of four Numeracy items and two prose passages. We only administered the reading comprehension portion. The Cronbach's alpha was 0.91 for the 36 items in the two prose passages in our sample.

### *2.4.4 Numeracy*

The numeracy scale from Lipkus et al. (2001) was used to assess participants' numeracy skills. It consists of three general numeracy items and eight expanded health numeracy items. Cronbach's alpha was 0.75 in our sample.

### *2.4.5 Ability Tests*

The Snellen visual acuity charts were used to assess participants' near vision and far vision. The Montreal Cognitive Assessment (Nasreddine et al. 2005) was used to assess participants' global cognitive function. It is a 30-point screening test designed to detect mild cognitive impairment (http://www.mocatest.org/). It measures aspects of attention, orientation, language, verbal memory, visuospatial, and executive function. A score that falls between 26 and 30 is considered normal. The time required to administer the test was approximately 10 minutes.

Participants completed the decision trials, self-report items, health literacy, and numeracy questions on a computer. They completed the MoCA using paper and pencil.

### 2.5 Procedure

Before the experiment, participants received a consent form explaining the research study. They consented to participate in the research study by signing the form. Then, they completed a questionnaire regarding demographics and health, and the ability tests. After that, participants were given both oral and written instructions about the decision task. Participants made medication decisions involving risks individually. To minimize any order effects, all decision trials were randomized for each participant. After all decision trials were completed, participants filled out the self-report items, followed by other questionnaires listed above. Finally, they were debriefed.

It took younger adults at most one hour and older adults at most one and a half hours to complete the entire experiment.

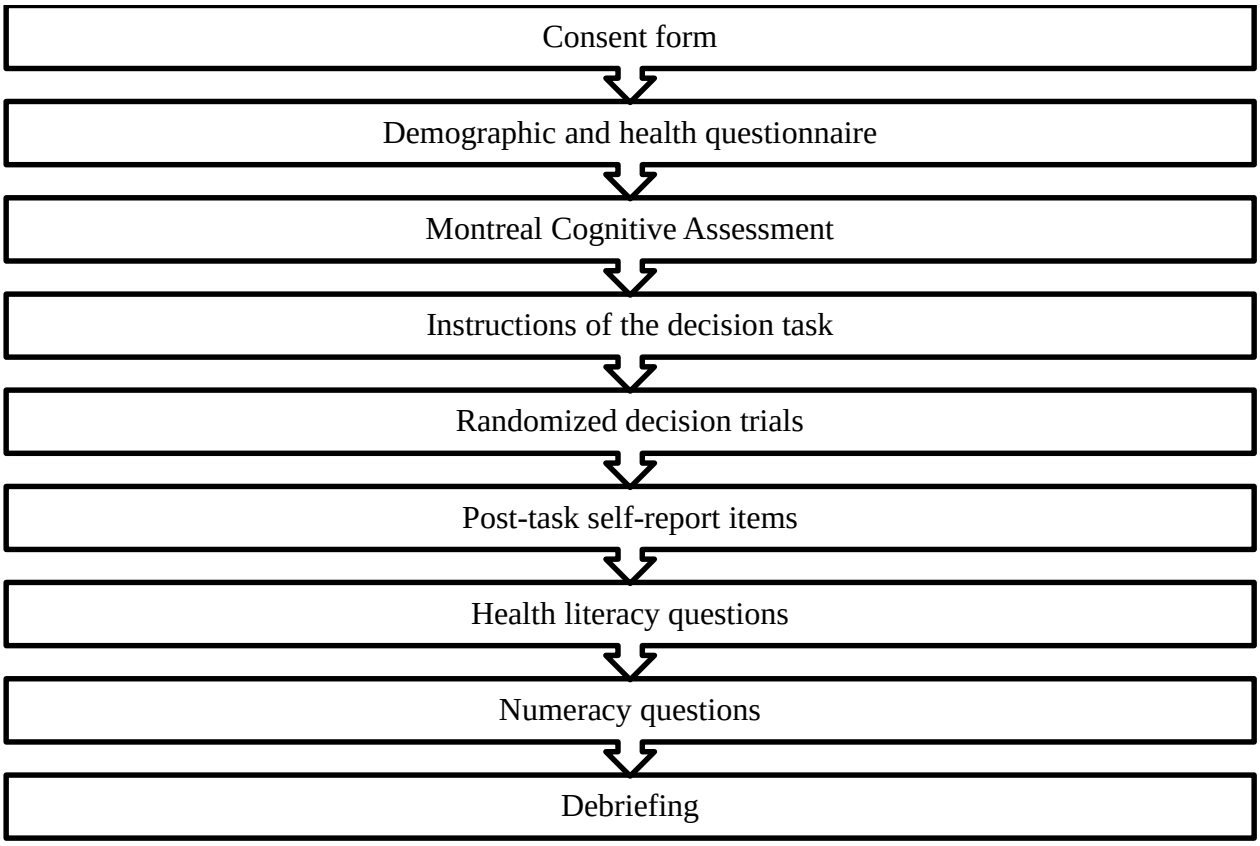


**Figure 2 – Procedure flow**

# 2 RESULTS

## 3.1 Catch Trial Analysis

I considered participants' performance on the four catch trials, and only included participants who chose the "rational" option on three or more trials. One older participant was excluded because of catch trial performance, resulting in 36 younger and 35 older participants for data analyses.

## 3.2 Medication Risk Taking (All Participants)

The dependent variable, the level of risk taking, was a proportion based on binomial outcomes (i.e., choosing the risky option vs. not choosing the risky option). The errors were non-normally distributed. Therefore, arcsine transformation was done on the proportion of risky options chosen on risk-disadvantageous, risk-neutral, and risk-advantageous trials.

Then, a mixed-design ANOVA was conducted with age as the between-subjects variable, and trial type as the within-subjects variable on the transformed level of medication risk taking for all participants. As expected, the effect of trial type was significant, $F(1.43, 98.34) = 117.48$, $p < .001$, $\omega^2 = .251$. There was a significant linear trend, $F(1, 69) = 143.73$, $p < .001$, indicating that the increase in risk taking from risk-disadvantageous trials ($M = .67$, $SD = .49$) to risk-neutral trials ($M = .99$, $SD = .67$) to risk-advantageous trials ($M = 1.33$, $SD = .85$) was proportionate. Overall, older adults ($M = .63$, $SD = .66$) were significantly less risk taking than younger adults ($M = 1.35$, $SD = .62$), $F(1, 69) = 31.89$, $p < .001$, $\omega^2 = .303$. However, there was an age by trial type interaction such that the effect of trial type depended on the age group, $F(1.43, 98.34) = 20.19$, $p < .001$, $\omega^2 = .049$. The age group x trial type linear partial interaction was significant, $F(1, 69) = 24.58$, $p <$

.001. The linear change in risk taking across trial types was smaller in older adults (risk-disadvantageous: *M* = .44, *SD* = .47; risk-neutral: *M* = .64, *SD* = .64; risk-advantageous: *M* = .82, *SD* = .79) than in younger adults (risk-disadvantageous: *M* = .89, *SD* = .39; risk-neutral: *M* = 1.33, *SD* = .50; risk-advantageous: *M* = 1.82, *SD* = .57). Figure 3 shows the results.

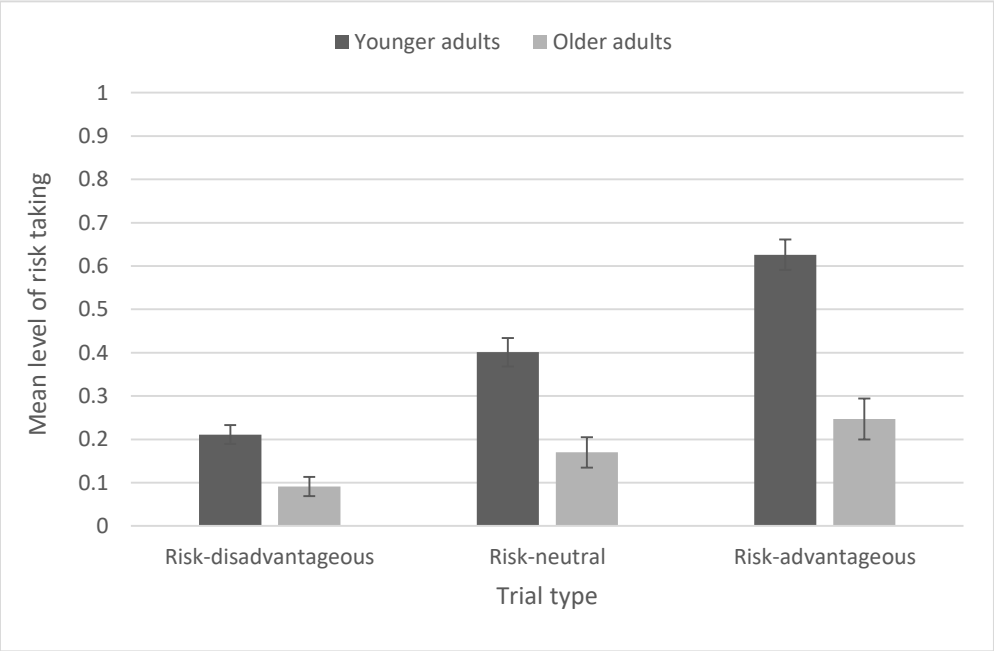


**Figure 3 - Young and old adults' level of risk taking (without the arcsine transformation) on risk-disadvantageous, risk-neutral, and risk-advantageous trials (error bars represent the standard error)**

Although the above bar chart showed the mean age trends, it obscured individual differences in sensitivity to the three trial types. Sensitivity was not a specific measure in the study. It refers to the increase in medication risk taking when the scenario changed from risk-disadvantageous to risk-neutral to risk-advantageous. Heatmaps allow the use of color to represent the magnitude of risk taking for each individual. Hence, they are useful in visualizing individual differences in risk-taking tendency on different trial types. In Figure 4, the heatmap on the left shows the medication risky choice data for individual younger adults and the heatmap on the right

shows the data for individual older adults. It is clear that older adults could be categorized as 2 groups: a group of older adults who took about the same level of risk on all trial types and another group of older adults who took more risks as risk taking became more advantageous. Based on the strong visual evidence of inter-individual variability among older adults, a post-hoc analysis on the risky choices at the individual level was performed. It revealed that 54.29% of older adults and 5.56% of younger adults showed little to no sensitivity to the different trial types (see individuals surrounded by the boxes in Figure 4). These insensitive older and younger adults' levels of risk taking on the risk-disadvantageous, risk-neutral, and risk-advantageous trials were within an intra-individual range of 3.33% while the levels of risk taking of the remaining sensitive participants had an intra-individual range of at least 13.33%. All except one of the insensitive participants were extremely risk averse, choosing the sure option on at least 96.67% of the trials.

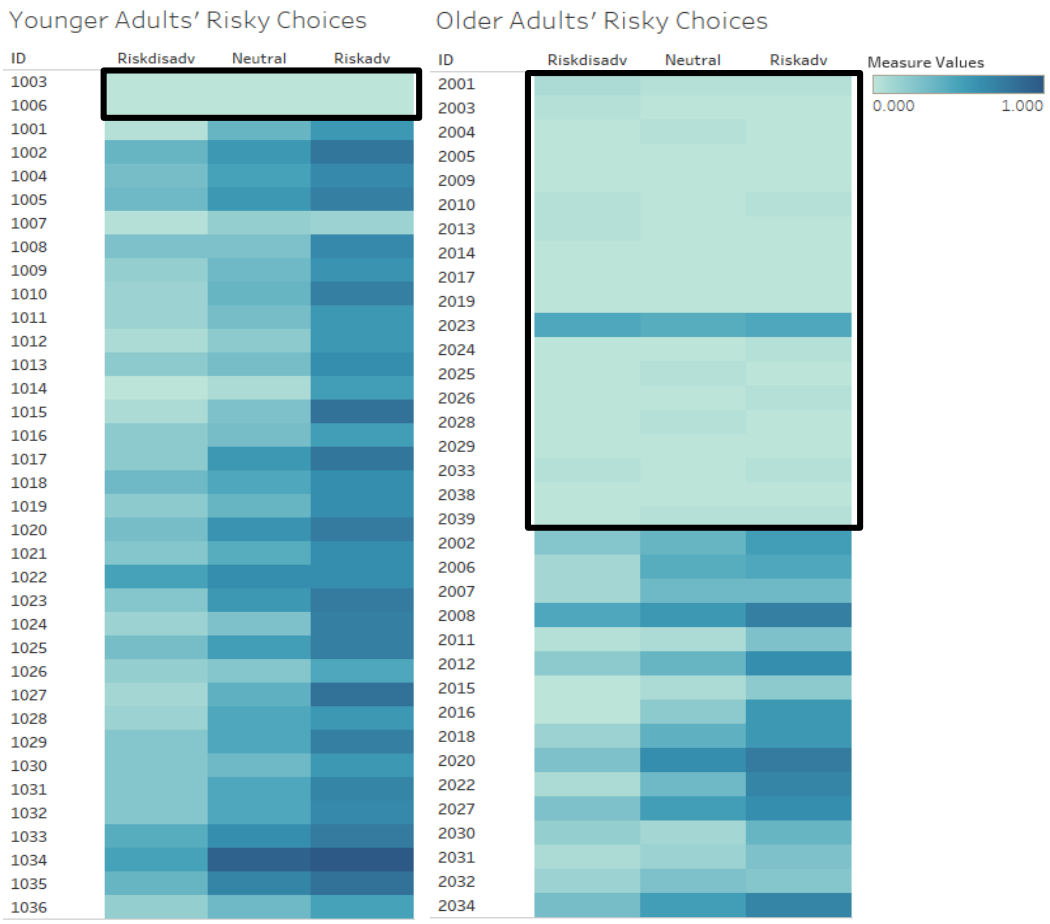


**Figure 4 - Heatmap showing individual younger and older adults' level of risk taking (from light blue: extremely risk averse to dark blue: extremely risk taking) on risk-disadvantageous, risk-neutral, and risk-advantageous trials**

### 3.3 Medication Risk Taking (Sensitive Participants)

To investigate how the larger proportion of older adults who were insensitive to trial types might have played a role in the age by trial type interaction, I conducted the same mixed-design ANOVA analyses on the level of medication risk taking for the subsample of sensitive participants (34 younger and 16 older adults). In comparison to the analyses including all participants, the main effects remained significant for trial type, $F(1.59, 76.33) = 202.62$, $p < .001$, $\omega^2 = .838$, and age group, $F(1, 48) = 6.59$, $p < .05$, $\omega^2 = .101$. The risk-taking pattern remained the same, increasing across the risk-disadvantageous, risk-neutral, and risk-advantageous trials. Older adults were more

risk averse than younger adults. However, the interaction effect of age group by trial type was no longer significant, $F(1.59, 76.33) = 1.84$, *ns*, $\omega^2 = .004$. Figure 5 shows the results.

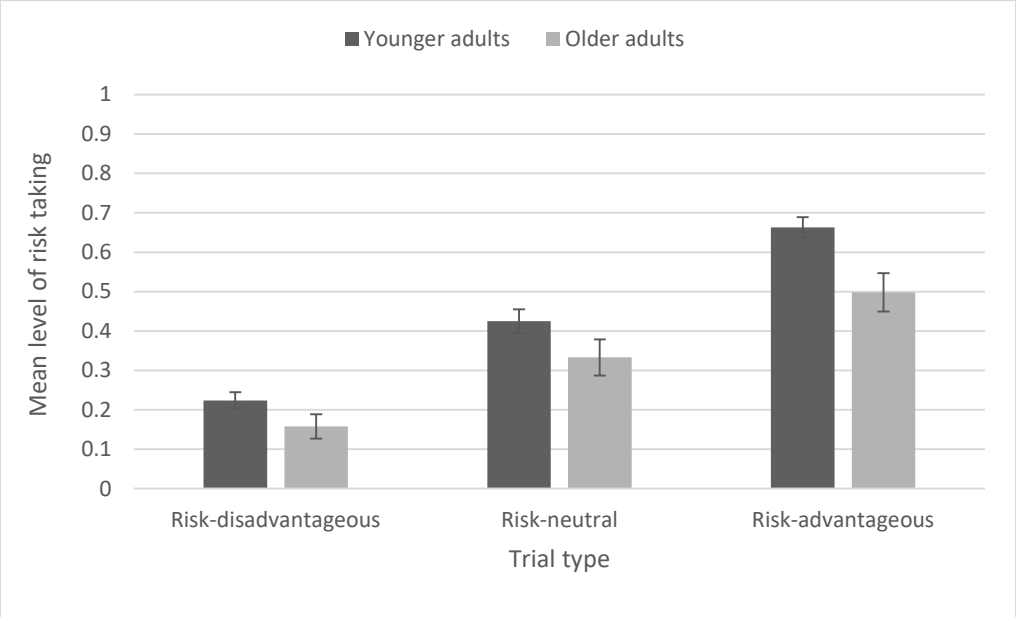


**Figure 5 - Young and old adults' level of risk taking (without the arcsine transformation) in the subsample of sensitive participants on risk-disadvantageous, risk-neutral, and risk-advantageous trials (error bars represent the standard error)**

In addition to the analysis on risky choices by trial type, it is valuable to break down sensitivity to trial types to sensitivity to expected value differences. I examined whether sensitive participants increased their level of risk taking with respect to the expected value difference between the sure and risky options, and whether sensitive older adults increased their level of risk taking in a similar way as did sensitive younger adults. Figure 6 shows that both younger and older sensitive participants took more risks when choosing the risky medication became more beneficial.

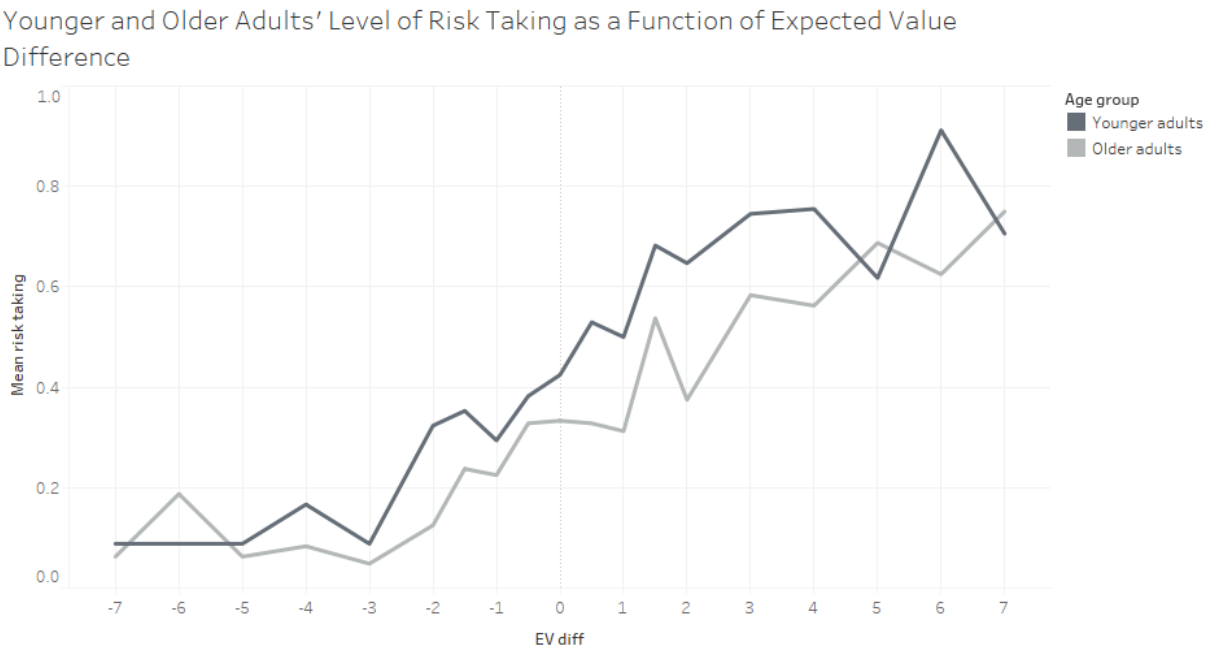


**Figure 6 – Younger and older sensitive participants' level of risk taking as a function of expected value difference between options (positive expected value differences mean the risky option had a higher expected value than the sure option, and vice versa)**

The following multilevel model was fitted to the data:

Level 1 equation:

$$\text{Risk taking} = \beta_{0j} + \beta_{1j}\,(\text{Expected value difference}_{ij}) + r_{ij}$$

Level 2 equations:

$$\beta_{0j} = \gamma_{01}(\text{Age\_group}_j) + \gamma_{00} + u_{0j}$$

$$\beta_{1j} = \gamma_{11}(\text{Age\_group}_j) + \gamma_{10} + u_{1j}$$

Overall mixed model equation:

$$\text{Risk taking} = \gamma_{01}(\text{Age\_group}_j) + \gamma_{10}(\text{Expected value difference}_{ij}) + \gamma_{11}(\text{Age\_group}_j) \times (\text{Expected value difference}_{ij}) + \gamma_{00} + u_{0j} + u_{1j}(\text{Expected value difference}_{ij}) + r_{ij}$$

$\gamma_{01}$, $\gamma_{10}$, $\gamma_{11}$, and $\gamma_{00}$ captured the fixed effects of age group, within-participant expected value difference, interaction between age group and expected value difference, and the intercept, respectively. $u_{0j}$, $u_{1j}$, and $r_{ij}$ captured the random effects of the intercept, slope, and error, respectively. Table 2 presents the estimates obtained from the model.

**Table 2: Parameter estimates and 95% confidence intervals (CIs) obtained by fitting the multilevel model to sensitive participants' data, predicting medication risk taking.**

| Parameter | Estimate | 95% CI |
|---|---|---|
| Fixed Effects | | |
| Intercept | 1.396*** | [1.246, 1.546] |
| Expected Value Difference | .187*** | [.163, .211] |
| Age Group | -.302* | [-.567, -.036] |
| Expected Value Difference x Age Group | -.022 | [-.065, .020] |
| Variance/ Covariance Parameters | | |
| Residual | .710*** | [.646, .781] |
| Intercept | .152*** | [.093, .251] |

**Table 2 continued.**

| | | |
|---|---|---|
| Intercept-Slope Covariance | .008 | [-.001, .017] |
| Slope | .002* | [.001, .005] |

*$p$<.05, **$p$<.01, ***$p$<.001.

The multilevel modeling results were consistent with the mixed-design ANOVA results. There were significant fixed effects of expected value difference and age group, but the expected value difference by age group interaction effect was not significant. Expected value difference (i.e., expected value of the risky option – expected value of the sure option) was positively associated with risk taking. The older age group was negatively associated with risk taking.

### 3.4 Individual Characteristics of Insensitive and Sensitive Older Participants

Additionally, I conducted separate independent samples t-tests to understand if older participants who were insensitive and sensitive to trial types differed on education, self-reported general health, numeracy, health literacy, MoCA, and post-task self-reported severity of sickness. Insensitive and sensitive older adults did not differ on any of these individual characteristic measures. Table 3 shows the t-test results.

**Table 3: Summary of t-test analyses on individual characteristics of insensitive and sensitive older adults.**

| | Insensitive Participants *Mean (SD)* | Sensitive Participants *Mean (SD)* | *t*-value | *df* | *p* |
|---|---|---|---|---|---|
| Education | 5.64 (1.34) | 5.81 (.98) | -.46 | 32.43 | .65 |
| General health | 3.63 (.76) | 3.38 (.62) | 1.08 | 33 | .29 |
| Numeracy | 7.79 (2.44) | 7.56 (2.63) | .26 | 33 | .79 |
| Health literacy | 31.95 (5.20) | 29.69 (7.52) | 1.05 | 33 | .30 |
| MoCA | 25.84 (2.14) | 25.19 (2.64) | .81 | 33 | .42 |
| Perceived severity of sickness | 4.79 (1.81) | 5.00 (1.75) | -.35 | 33 | .73 |

# 3 DISCUSSION

Findings from the present study provide insights into younger and older adults' risky decision making for medications. Confirming our expectation, relative to situations wherein risk taking and risk aversion were equally favorable, younger and older adults took more risks when risk taking was beneficial, and they took fewer risks when risk aversion was beneficial. Overall, older adults were less risk taking than younger adults. However, the effect of trial type differed between the two age groups such that the linear change in risk taking among older adults was smaller than that among younger adults across risk-disadvantageous, risk-neutral, and risk-advantageous scenarios. Focusing only on participants that demonstrated sensitivity to trial types older adults remained less risk taking, but the risk-taking trend on different trial types no longer depended on the age group. The large proportion of insensitive older adults could account for the age difference in increase in risk taking across situations. Further investigation at the more granular level of expected value differences regarding sensitive younger and older adults' choices yielded consistent results.

## 4.1 Theoretical Implications

Findings from the study suggested that younger and older adults could be essentially classified into three groups: younger adults who were sensitive to expected value differences, older adults who took fewer risks than did younger adults but were sensitive to expected value differences, and older adults who were extremely risk averse and exhibited no sensitivity to expected value differences.

The finding that older adults could be categorized as two groups is a novel finding, suggesting that older individuals likely relied on different levels of gist when making the medication risky decisions. Older adults' choices could be explained by fuzzy-trace theory (Reyna & Brainerd, 2011; Reyna et al., 2015) and goal orientation (Ebner et al., 2006), whereas insensitive older adults' choices could be explained by fuzzy-trace theory (Reyna & Brainerd, 2011; Reyna et al., 2015) and people's general risk aversion tendency (Tversky & Kahneman, 1986).

According to fuzzy-trace theory, people prefer to use simpler representations as the bottom-line meaning in discriminating between options (Reyna & Brainerd, 2011; Reyna et al., 2015). When categorical something-nothing contrasts are emphasized as in typical risky-choice problems, individuals are more likely to choose the risky option in the negative frame because they find the zero-loss outcome attractive (Reyna, Chick, Corbin, & Hsia, 2014). However, the risky option in the current study did not include a zero-loss outcome because an outcome of recovering in zero days is not likely to happen in everyday medical contexts.

Sensitive older adults' lower risk-taking tendency relative to younger adults suggests that the former might have used an ordinal gist representation. They might have represented the gist of the decision scenario as choosing between the risky option: some chance of fully recovering in a maximum number of days and some chance of fully recovering in a minimum number of days, and the sure option: fully recovering in a few/some/many days (corresponding to risk-disadvantageous, risk-neutral, and risk-advantageous trials). When older adults have a goal to minimize losses (Ebner et al, 2006), they may tend to prefer the sure medication option relative to younger adults. Meanwhile, sensitive older adults were more risk taking in risk-advantageous situations than in other situations. This was likely because they were motivated to reduce the loss

of fully recovering in many days by choosing the risky medication option which had a potential outcome of fully recovering in a minimum number of days.

Insensitive older adults who chose the medication with a sure outcome in every situation regardless of expected value differences likely used a categorical gist representation. To ensure that the risky option was sometimes less favorable, equally favorable, or more favorable, the precise treatment outcome and probability information was changed across trials. However, if older adults were not taking into account the verbatim representation of choice options in making the medication decisions, they would not be responding correspondingly to the risk-disadvantageous, risk-neutral, and risk-advantageous trials. The observation of insensitive older adults suggests that they likely extracted the meaning of the decision scenario in a fuzzy way as choosing between a sure medication option and a risky medication option. Given this gist representation and people's general risk aversion tendency (Tversky & Kahneman, 1986), insensitive older adults thus chose the sure medication option all the time to avoid uncertainty.

The present study adds to the literature in that it investigated age differences in risk taking in the medical domain, which has heretofore been understudied. Despite the lack of overall age differences in the negative frame, the Best and Charness (2015) meta-analysis showed that the age effect was present in large-amount mortality scenarios, but not in other scenarios. Thus, factors such as amount (i.e., number of days until full recovery in the current study) and domain influence the presence of age-related differences in risk taking. Older adults' greater risk aversion in the present study could be additional evidence that age-related differences in risk preferences are context dependent. People may evaluate the options differently in situations involving money, human lives, or treatment of illness. Age-related differences in risk taking in the medical domain require further exploration.

The current study only makes a novel contribution to the literature, it also adds support to previous findings. Overall, older adults were less sensitive to expected value differences than younger adults, consistent with the idea that older adults are more likely to use gist processing whereas younger adults are more likely to use verbatim processing in making decisions (Peters et al., 2007; Reyna & Brainerd, 2011). Additionally, both groups of older adults took fewer risks than did younger adults, consistent with the meta-analytic finding of age-related differences in negatively-framed large-amount mortality scenarios (Best & Charness, 2015).

When only sensitive participants were considered, there was no longer an age group by trial type interaction effect. The significant reduction in effect size after excluding insensitive participants suggests that the age group by trial type interaction was mainly attributable to the large proportion of older adults who were not responsive to trial types and were extremely risk averse in all decision situations. Given the small sample size in the follow-up analyses, it is inconclusive whether the risk-taking trend across risk-disadvantageous, risk-neutral, and risk-advantageous situations is different for younger versus older age group among those showing at least some sensitivity. While it would be valuable to fit computational models to participants' risky choices, these models require that people demonstrate at least some sensitivity to the outcome and/or probability information presented to them. The small sample of sensitive older adults would limit the insights that modeling analyses could offer. Future research should investigate whether sensitive younger and older adults adjust to the decision scenarios to differential extents.

The finding that none of the potential variables predicted older adults' sensitivity to trial types could be due to the small sample size of older adults. It could also indicate that other variables should be considered as the explanation. Individual differences in medication decision-making

experience and decision strategies might be able to account for the variability in older adults' risky choices. Future work should explore these possibilities.

Although experience in making medication decisions was not measured directly, there was likely a large within-group variation in medication decision-making experience among the older adults given the large within-group variation in the number of medications each participant took. A study investigating risky decision making among intelligence agents, college students, and post-college adults showed that the tendency to base decisions on the gist representation (meaning) increased with experience in the domain (Reyna et al., 2014). Therefore, older adults who are more experienced in choosing between medications may tend to rely on the gist of the choice options in making the decisions whereas those who are less experienced may be more likely to rely on the verbatim representation. A lack of responsiveness to trial types in the present study could reflect gist-based decision making. Future research could test the association between domain-specific decision-making experience and sensitivity to risk-disadvantageous, risk-neutral, and risk-advantageous conditions.

Individual differences in decision strategies could be another factor that contributed to older adults' sensitivity to trial types (or lack thereof). Some older adults might use emotion-focused strategies to maximize positive emotion because of a motivational shift in their goals or age-related declines in cognitive resources (Carstensen, Isaacowitz, & Charles, 1999; Labouvie-Vief, 2003; Labouvie-Vief & Medler, 2002; Löckenhoff & Carstensen, 2007); however, others might use information-focused strategies. When people use emotion-focused strategies and place a great emphasis on valence, they might regard other information such as probabilities as irrelevant in decision making (Rivers, Reyna, & Mills, 2008). The selection of emotion-focused strategies among some older adults in our sample might have led them to choose the sure option regardless

of detailed information presented in the task. Additional research efforts are needed to deepen our understanding of younger and older adults' strategy use and its relation to risk preferences across risk-disadvantageous, risk-neutral, and risk-advantageous situations.

### 4.2 Practical Implications

Examining age-related differences in medication risk seeking enabled us to understand more about younger and older adults' risk preferences and hence provided us with the knowledge to devise appropriate decision aids for each group. This is especially important as policies in the US increasingly emphasize patient-centered care, which means that patients now have a greater responsibility for making their own health care decisions (Mitzner, McBride, Barg-Walkow, & Rogers, 2013). The present study offers evidence that a significant proportion of older adults tend to show less sensitivity to objective probability and outcome information. Thus, risk communication professionals may want to train older adults to attend more to these kinds of information, or change the presentation of materials to highlight the meaning of these aspects to older adults. Future research should examine these possibilities and contribute to the development of tools to facilitate younger and older adults' risky decision making in the medical domain.

### 4.3 Conclusion

Maintaining health and recovering from sickness require individuals to choose between medications. The current study investigated younger and older adults' risky decision making with the use of a medication choice task. Older adults were less risk taking than younger adults, and older adults showed a smaller increase in their risk-taking tendency across situations than did younger adults. This interaction was explained by the large number of insensitive older participants. More than half of older adults were insensitive in that they were extremely risk averse

in all situations including situations that favor risk taking. Although some older adults appeared to make their medication risky decisions according to exact probabilities and outcomes, a substantial proportion of older adults in our sample seemed to have a great preference for certainty and make gist-based medication risky choices. In practice, medical professionals should focus on explaining the meaning of different medication options to older adults who rely on gist processing, rather than merely present numerical information to these older adults. As the next steps, researchers could conduct a study on a larger sample of younger and older adults to better understand whether older adults are less responsive to risk-disadvantageous, risk-neutral, and risk-advantageous situations than younger adults, and the individual characteristics that could predict the sensitivity to expected value difference between options among older adults.

## APPENDIX A. INSTRUCTIONS FOR PARTICIPANTS

In the following task you will be making medication decisions. In each situation there will be a choice between two medications with different treatment outcomes and probabilities. For example, you might see the following display on the computer screen:

You have been diagnosed with a bacterial infection. Which antibiotic medication would you choose?

| Medication A | Medication B |
|---|---|
| 30% chance of fully recovering in 30 days<br>and<br>70% chance of fully recovering in 10 days | 100% chance of fully recovering in 16 days |

This means that you have a choice between one dose of medication A, with a 30% chance of fully recovering in 30 days and a 70% chance of fully recovering in 10 days, and one dose of medication B, with a 100% chance of fully recovering in 16 days. Choices are made by pressing the ‘z’ or ‘/’ key on the computer keyboard. If you would choose the medication on the left side of the screen, press the ‘z’ key. If you would choose the medication on the right side of the screen, press the ‘/’ key.

Another example of what you might see on the computer screen is the following display:

You have been diagnosed with a bacterial infection. Which antibiotic medication would you choose?

| Medication A | Medication B |
| --- | --- |
| 100% chance of fully recovering in 11 days | 75% chance of fully recovering in 15 days<br>and<br>25% chance of fully recovering in 5 days |

This means that you have a choice between one dose of medication A, with a 100% chance of fully recovering in 11 days, and one dose of medication B, with a 75% chance of fully recovering in 15 days and a 25% chance of fully recovering in 5 days. Choices are made by pressing the 'z' or '/' key on the computer keyboard. If you would choose the medication on the left side of the screen, press the 'z' key. If you would choose the medication on the right side of the screen, press the '/' key.

Finally, although these medications are hypothetical, please imagine what your choice would be if they were real.

We will do several practice items. Do you have any questions?

## APPENDIX B. RISK MAGNITUDES AND NUMBER OF DAYS OF RECOVERY ON ALL TRIALS

| Risk-neutral | | | | | EV diff | Risk-disadvantageous | | | | | EV diff | Risk-advantageous | | | | | EV diff |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Risky | 10% | 30 | 90% | 10 | 0 | 10% | 30 | 90% | 10 | 1 | | 10% | 30 | 90% | 10 | -1 | |
| Sure | | 12 | | | | | 11 | | | | | | 13 | | | | |
| Risky | 20% | 30 | 80% | 10 | 0 | 20% | 30 | 80% | 10 | 3 | | 20% | 30 | 80% | 10 | -3 | |
| Sure | | 14 | | | | | 11 | | | | | | 17 | | | | |
| Risky | 40% | 30 | 60% | 10 | 0 | 40% | 30 | 60% | 10 | 5 | | 40% | 30 | 60% | 10 | -5 | |
| Sure | | 18 | | | | | 13 | | | | | | 23 | | | | |
| Risky | 60% | 30 | 40% | 10 | 0 | 60% | 30 | 40% | 10 | 2 | | 60% | 30 | 40% | 10 | -2 | |
| Sure | | 22 | | | | | 20 | | | | | | 24 | | | | |
| Risky | 80% | 30 | 20% | 10 | 0 | 80% | 30 | 20% | 10 | 3 | | 80% | 30 | 20% | 10 | -3 | |
| Sure | | 26 | | | | | 23 | | | | | | 29 | | | | |
| Risky | 90% | 30 | 10% | 10 | 0 | 90% | 30 | 10% | 10 | 1.5 | | 90% | 30 | 10% | 10 | -1.5 | |
| Sure | | 28 | | | | | 26.5 | | | | | | 29.5 | | | | |
| Risky | 10% | 25 | 90% | 5 | 0 | 10% | 25 | 90% | 5 | 1 | | 10% | 25 | 90% | 5 | -1 | |
| Sure | | 7 | | | | | 6 | | | | | | 8 | | | | |

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Risky | 20% | 25 | 80% | 5 | 0 | 20% | 25 | 80% | 5 | 3 | 20% | 25 | 80% | 5 | -3 |
| Sure | | 9 | | | | | 6 | | | | | 12 | | | |
| Risky | 40% | 25 | 60% | 5 | 0 | 40% | 25 | 60% | 5 | 3 | 40% | 25 | 60% | 5 | -3 |
| Sure | | 13 | | | | | 10 | | | | | 16 | | | |
| Risky | 60% | 25 | 40% | 5 | 0 | 60% | 25 | 40% | 5 | 4 | 60% | 25 | 40% | 5 | -4 |
| Sure | | 17 | | | | | 13 | | | | | 21 | | | |
| Risky | 80% | 25 | 20% | 5 | 0 | 80% | 25 | 20% | 5 | 3 | 80% | 25 | 20% | 5 | -3 |
| Sure | | 21 | | | | | 18 | | | | | 24 | | | |
| Risky | 90% | 25 | 10% | 5 | 0 | 90% | 25 | 10% | 5 | 1 | 90% | 25 | 10% | 5 | -1 |
| Sure | | 23 | | | | | 22 | | | | | 24 | | | |
| Risky | 10% | 20 | 90% | 10 | 0 | 10% | 20 | 90% | 10 | 0.5 | 10% | 20 | 90% | 10 | -0.5 |
| Sure | | 11 | | | | | 10.5 | | | | | 11.5 | | | |
| Risky | 20% | 20 | 80% | 10 | 0 | 20% | 20 | 80% | 10 | 1.5 | 20% | 20 | 80% | 10 | -1.5 |
| Sure | | 12 | | | | | 10.5 | | | | | 13.5 | | | |
| Risky | 40% | 20 | 60% | 10 | 0 | 40% | 20 | 60% | 10 | 3 | 40% | 20 | 60% | 10 | -3 |
| Sure | | 14 | | | | | 11 | | | | | 17 | | | |
| Risky | 60% | 20 | 40% | 10 | 0 | 60% | 20 | 40% | 10 | 3 | 60% | 20 | 40% | 10 | -3 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sure | 16 | | | | | 13 | | | | 19 | | |
| Risky | 80% | 20 | 20% | 10 | 0 | 80% | 20 | 20% | 10 | 1.5 | 80% | 20 | 20% | 10 | -1.5 |
| Sure | 18 | | | | | 16.5 | | | | | 19.5 | | | | |
| Risky | 90% | 20 | 10% | 10 | 0 | 90% | 20 | 10% | 10 | 0.5 | 90% | 20 | 10% | 10 | -0.5 |
| Sure | 19 | | | | | 18.5 | | | | | 19.5 | | | | |
| Risky | 10% | 15 | 90% | 5 | 0 | 10% | 15 | 90% | 5 | 0.5 | 10% | 15 | 90% | 5 | -0.5 |
| Sure | 6 | | | | | 5.5 | | | | | 6.5 | | | | |
| Risky | 20% | 15 | 80% | 5 | 0 | 20% | 15 | 80% | 5 | 1 | 20% | 15 | 80% | 5 | -1 |
| Sure | 7 | | | | | 6 | | | | | 8 | | | | |
| Risky | 40% | 15 | 60% | 5 | 0 | 40% | 15 | 60% | 5 | 3 | 40% | 15 | 60% | 5 | -3 |
| Sure | 9 | | | | | 6 | | | | | 12 | | | | |
| Risky | 60% | 15 | 40% | 5 | 0 | 60% | 15 | 40% | 5 | 3 | 60% | 15 | 40% | 5 | -3 |
| Sure | 11 | | | | | 8 | | | | | 14 | | | | |
| Risky | 80% | 15 | 20% | 5 | 0 | 80% | 15 | 20% | 5 | 1 | 80% | 15 | 20% | 5 | -1 |
| Sure | 13 | | | | | 12 | | | | | 14 | | | | |
| Risky | 90% | 15 | 10% | 5 | 0 | 90% | 15 | 10% | 5 | 0.5 | 90% | 15 | 10% | 5 | -0.5 |
| Sure | 14 | | | | | 13.5 | | | | | 14.5 | | | | |

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Risky | 10% | 30 | 90% | 5 | 0 | | 10% | 30 | 90% | 5 | 1.5 | | 10% | 30 | 90% | 5 | -1.5 |
| Sure | | 7.5 | | | | | | 6 | | | | | | 9 | | | |
| Risky | 20% | 30 | 80% | 5 | 0 | | 20% | 30 | 80% | 5 | 4 | | 20% | 30 | 80% | 5 | -4 |
| Sure | | 10 | | | | | | 6 | | | | | | 14 | | | |
| Risky | 40% | 30 | 60% | 5 | 0 | | 40% | 30 | 60% | 5 | 7 | | 40% | 30 | 60% | 5 | -7 |
| Sure | | 15 | | | | | | 8 | | | | | | 22 | | | |
| Risky | 60% | 30 | 40% | 5 | 0 | | 60% | 30 | 40% | 5 | 6 | | 60% | 30 | 40% | 5 | -6 |
| Sure | | 20 | | | | | | 14 | | | | | | 26 | | | |
| Risky | 80% | 30 | 20% | 5 | 0 | | 80% | 30 | 20% | 5 | 4 | | 80% | 30 | 20% | 5 | -4 |
| Sure | | 25 | | | | | | 21 | | | | | | 29 | | | |
| Risky | 90% | 30 | 10% | 5 | 0 | | 90% | 30 | 10% | 5 | 1.5 | | 90% | 30 | 10% | 5 | -1.5 |
| Sure | | 27.5 | | | | | | 26 | | | | | | 29 | | | |

# APPENDIX C. CATCH TRIALS

You have been diagnosed with a bacterial infection. Which antibiotic medication would you choose?

| | |
|---|---|
| Medication A<br>A 60% chance of fully recovering in 30 days<br>and<br>a 40% chance of fully recovering in 20 days | Medication B<br>A 100% chance of fully recovering in 15 days |

You have been diagnosed with a bacterial infection. Which antibiotic medication would you choose?

| | |
|---|---|
| Medication A<br>A 20% chance of fully recovering in 25 days<br>and<br>a 80% chance of fully recovering in 10 days | Medication B<br>A 100% chance of fully recovering in 5 days |

You have been diagnosed with a bacterial infection. Which antibiotic medication would you choose?

| | |
|---|---|
| Medication A<br>A 40% chance of fully recovering in 20 days<br>and<br>a 60% chance of fully recovering in 5 days | Medication B<br>A 100% chance of fully recovering in 3 days |

You have been diagnosed with a bacterial infection. Which antibiotic medication would you choose?

| | |
|---|---|
| Medication A<br>A 90% chance of fully recovering in 30 days<br>and<br>a 10% chance of fully recovering in 15 days | Medication B<br>A 100% chance of fully recovering in 10 days |

# APPENDIX D. POST-TASK SELF-REPORT ITEMS

1. In this study, when you were making choices about medications, how severe did you think the sickness was? (from 1 not severe to 7 severe)
2. What specific illnesses were you thinking about when you made the choices about medications?

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